STUDY ON INFRARED THERMOGRAPHIC INSPECTION OF DE-BONDED LAYER OF AIRPORT FLEXIBLE PAVEMENT

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ABSTRACT

The impact acoustics method using a hammer on the surface of airport flexible pavements is used to find layer debonding between asphalt concrete layers. However, it takes many days to investigate the existence of layer debonding in a huge area in an airport with the impact acoustics method. As surface temperature on the debonded area tend to decrease in the night time compared with that on the non-debonded area, field tests on the airport were conducted to verify the applicability of inspection with infrared thermography. As a result, the following conclusions were obtained: (1) It is confirmed that layer debonding at the depth of 40 mm – 70 mm from the surface of pavements can be found by surface temperature differences measured by infrared thermography; (2) Existence of rubber on the surface of the runway makes it difficult to identify the layer debonding by infrared thermography, though the effect of grooves on the surface of the runway is not large; (3) From the results of field tests and thermal analysis of flexible pavement, the volume of solar radiation and the difference between maximum and minimum temperatures in a day affects the surface temperature difference between debonded and non-debonded areas.

INTRODUCTION

In July 2000, slippage failure occurred at the end of the runway of Nagoya Airport in Japan due to loss of bond between the surface and binder course as shown in Figure 1. The thickness of the surface course was 5 cm, the slippage area was 4 m wide and 8 m long, and the runway had to be closed for a time [1]. The surface course in this area had been constructed in 1999. The reason of this slippage was due to the top layer not properly bonded to the layer below and the large horizontal load of aircraft at takeoff.

Figure 1. Slippage failure Due to Loss of Bond at Nagoya Airport.

Following this incident, airport flexible pavements have been inspected by an impact acoustic method using a hammer on the surface to detect de-bonded areas between asphalt concrete layers. In this inspection method, the inspector walks around, repeatedly hits the surface of the pavement by a hammer, listens to the tone of the sound, and thus estimates the de-bonded positions. However, this method takes many days for a large airport. On the other hand, infrared thermography is widely used to detect the positions of defects within the concrete piers of roads and railways [2]. The method is based on the surface temperature difference between bonded and de-bonded areas. Since heat transfer is blocked between layers due to air in a de-bonded area (which acts as an insulator), the surface temperature at that area decreases at night and increases in the day compared with that on bonded areas as shown in Figure 2.

This paper presents the results of field trials and thermal analysis conducted to verify the applicability of the infrared thermographic inspection method to airfield pavements.

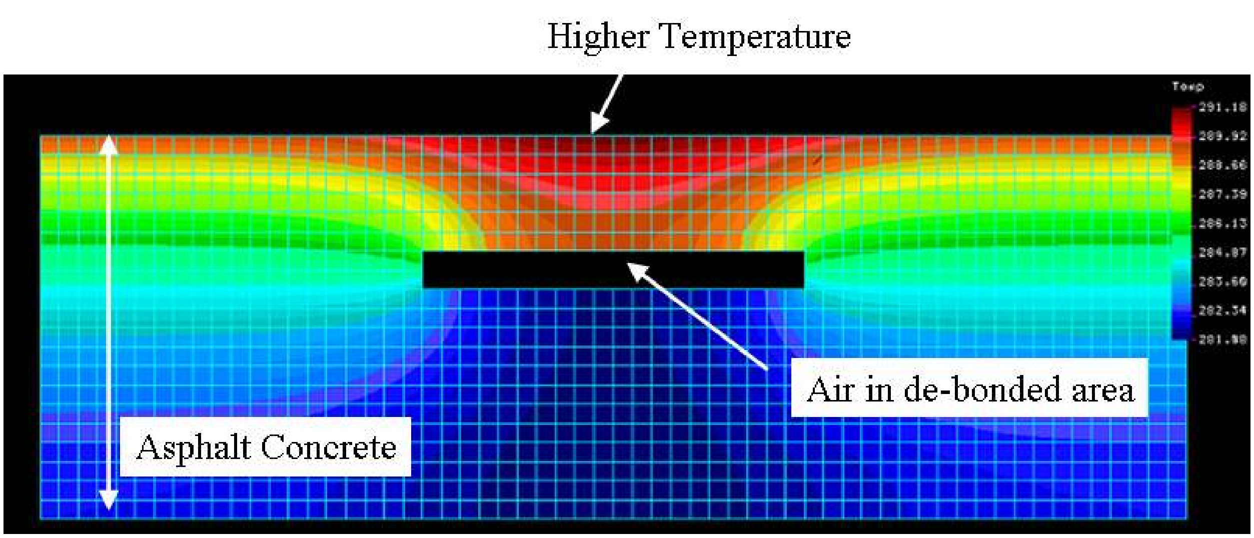


Figure 2. Example Image of Thermal Analysis (Daytime Condition).

FIELD TRIAL OF INFRARED INSPECTION METHOD

To verify the applicability of the infrared thermographic inspection method to airfield pavements, a trial inspection was conducted at Naha Airport in September. This is one of the largest airports in Japan and is located in southeastern Japan as shown in Figure 3. De-bonded areas between layers were found at the end of the runway by the impact acoustic method with hammer in the summer of 2005. The runway-taxiway intersection near the end of the runway, measuring 10 m by 10 m, was used for the trial.

First, the inspection area was divided into small squares of 50 cm by 50 cm, and then the area was inspected using the impact acoustic method with hammer and the positions of de-bonding were marked by light chalk lines. After marking, the inspector took infrared images of the inspection area using thermography with the specifications shown in Table 1. The infrared images were taken from a height of 10 m every 30 min from 0:30 a.m. to 5:30 a.m. Air temperature and intensity of solar radiation were measured during this trial. Figure 4 shows the weather conditions of the inspection days. The weather was fine on the second day and occasionally cloudy in other days.

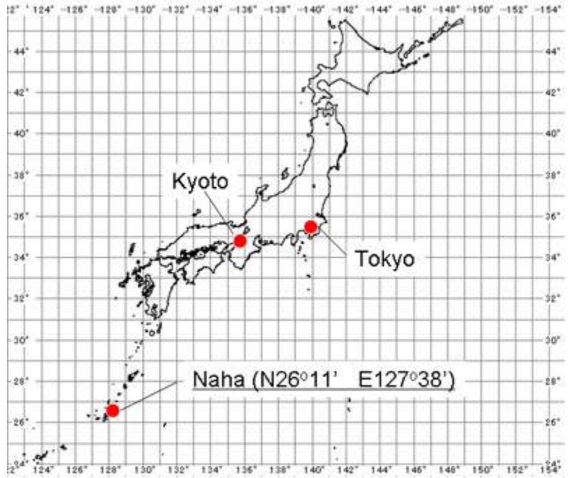


Figure 3. Location of Naha Airport.

Table 1.
Specifications of thermography used for inspection

Item	Specification
Measurement range	–40 to 500 °C
Temperature resolution	Better than 0.06 °C with averaging
Accuracy	±2 °C
Field of view	30.6° (H) × 23.1° (V) (with 22-mm standard lens)
Spatial resolution	1.68 mrad

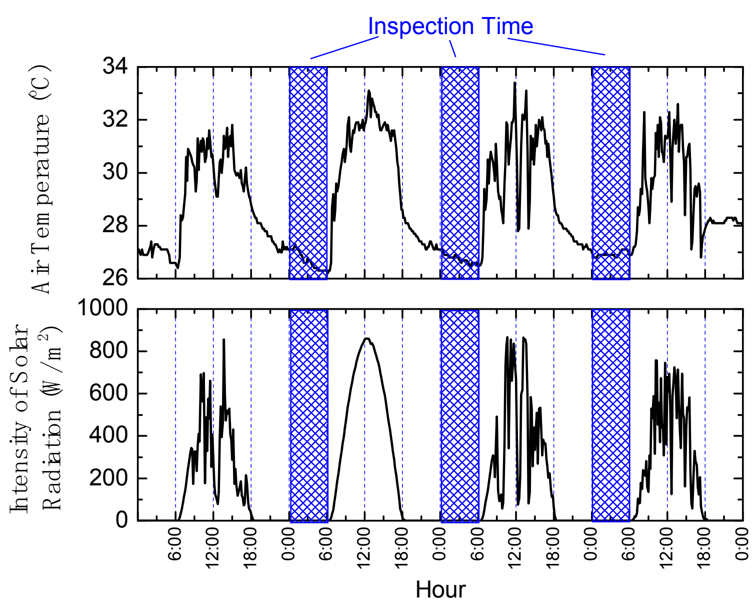


Figure 4. Weather Conditions on Inspection Days.

Figure 5 shows a visible image of the inspection area from a height of 10 m. Circular marks indicate de-bonded areas found by the impact acoustic method. Figure 6 shows an infrared image of the same inspection area. In Figure 6, the black areas were cooler than the white areas. Comparing these two images, the low-temperature areas generally match the de-bonded areas found by the impact acoustic method.

After taking infrared images of the inspection area, core boring was carried out at seven low-temperature areas to confirm the depth of de-bonding. As a result, we confirmed de-bonding at all seven areas at a depth of 40 – 70 mm as shown in Figure 7. Figure 8 shows the change of temperature measured on surface of both the de-bonded area (the depth of de-bonding is 50 mm) and its surrounding by using infrared thermography. These results clearly show that the surface temperature on the de-bonded area was lower than that of its surrounding from midnight to morning.

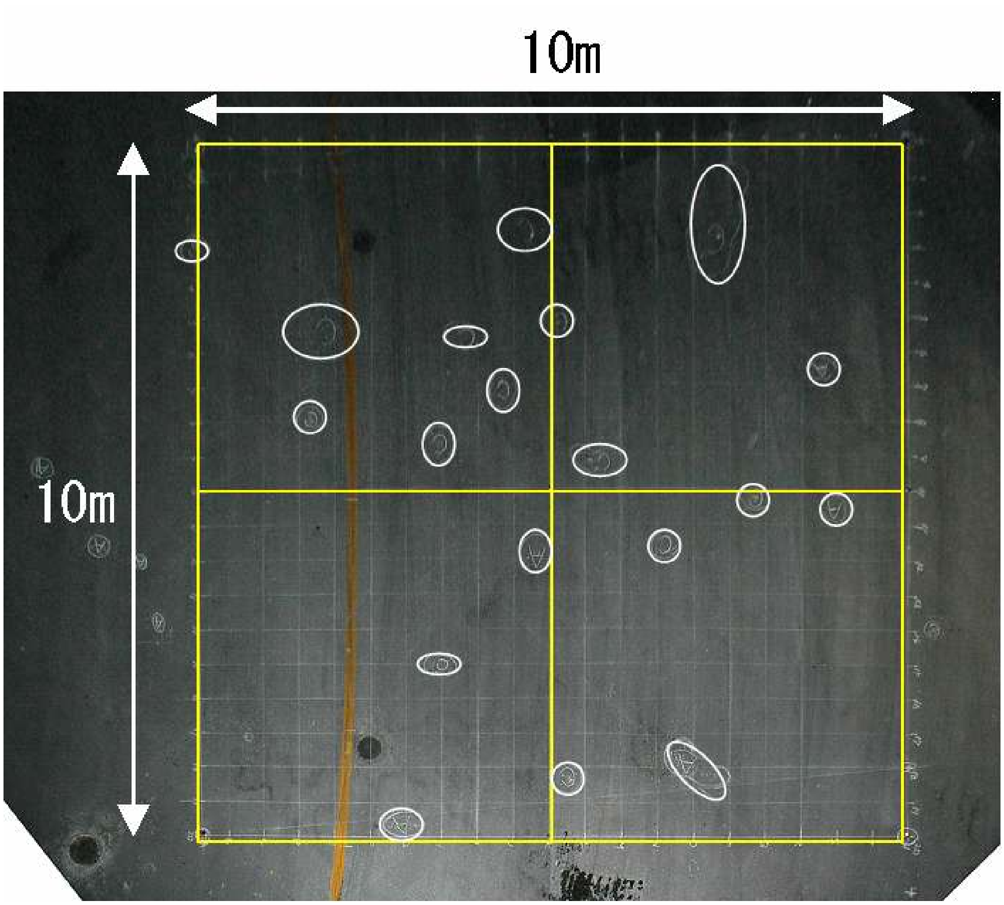


Figure 5. Visible Image of Inspection Area.

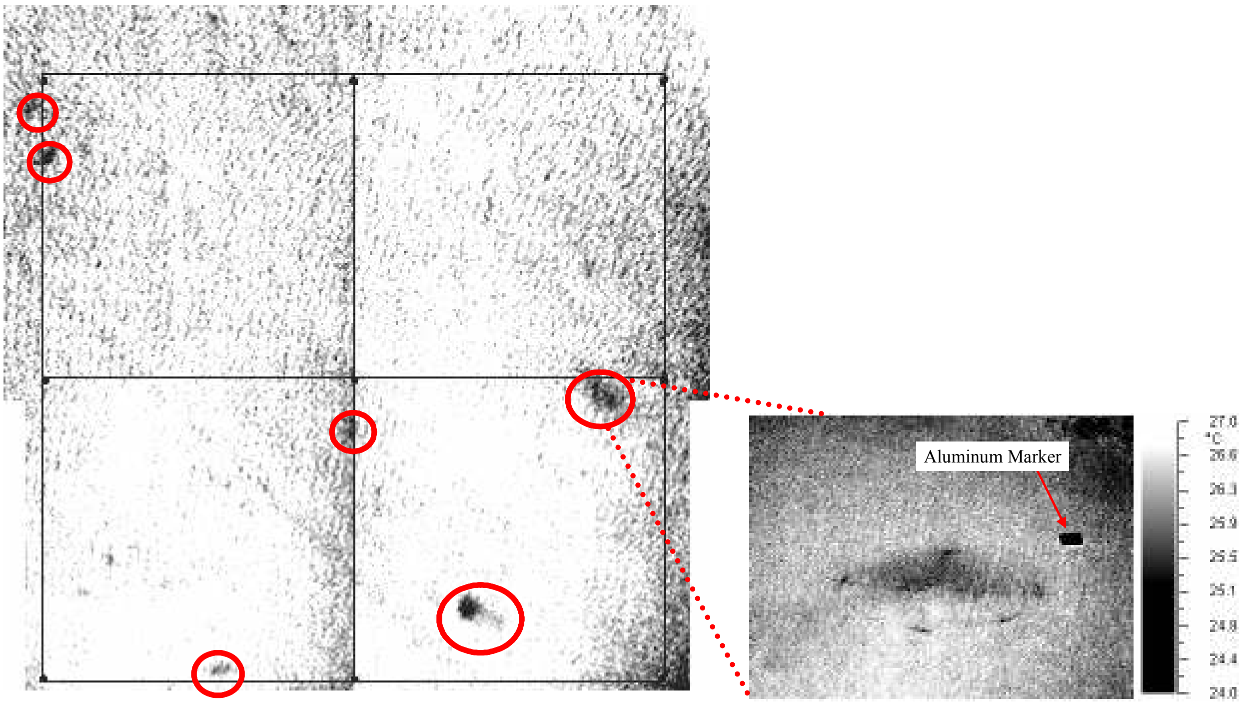


Figure 6. Infrared Image of Inspection Area (Black = Low Temperature).

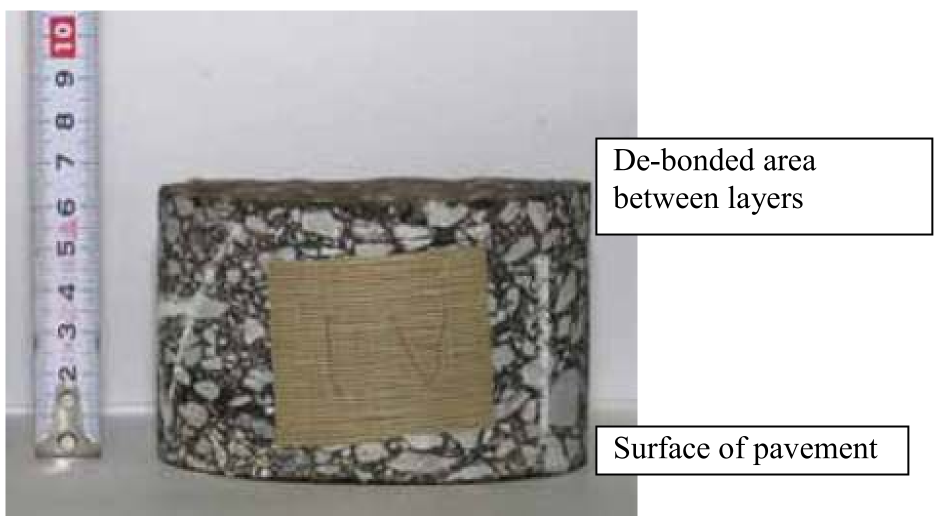


Figure 7. Core Sample Obtained at De-bonded Area.

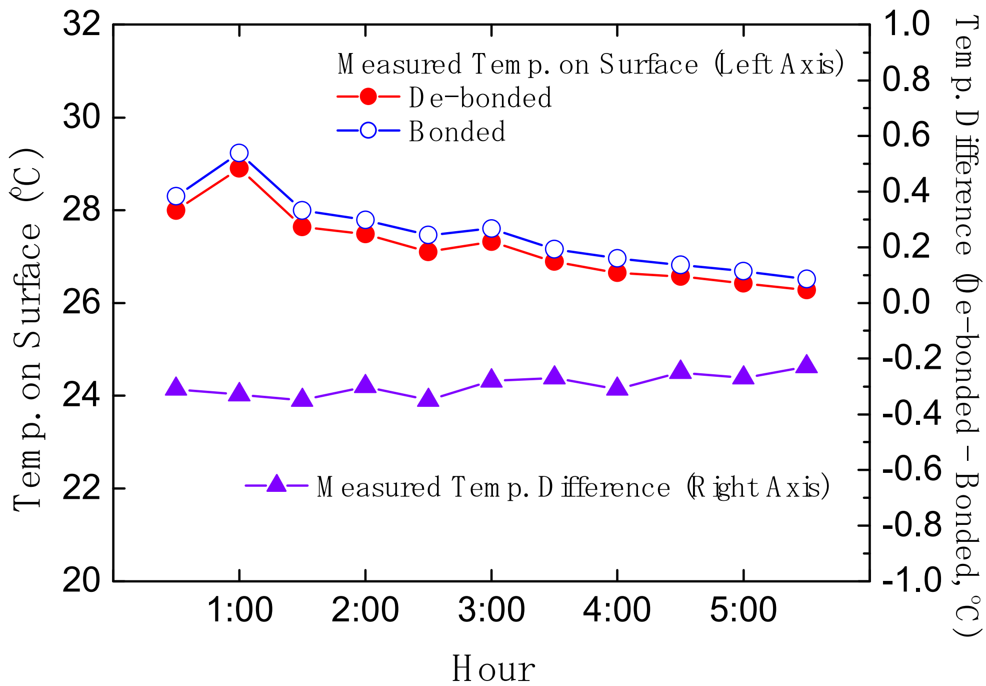


Figure 8. Variation of Temperature and Temperature Difference on Surface.

EFFECT OF GROOVES ON SURFACE

Grooves, as shown in Figure 9, are constructed on the surfaces of all runways and some taxiways at all airports maintained by the Civil Aviation Bureau of Japan to drain rain water from the airfield pavement to the shoulder as quickly as possible. However, in the first trial to detect low-temperature areas in infrared images, the grooves interfered because the striped pattern due to grooves was seen clearly in case the image was taken from low height. To solve this problem, another trial inspection was conducted by changing the depression angle at which infrared thermographic images were taken.

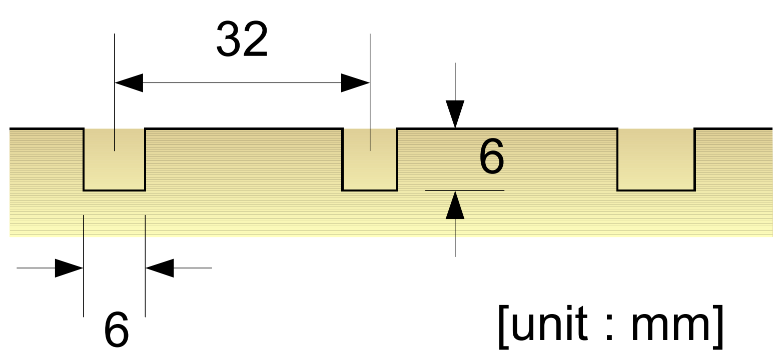
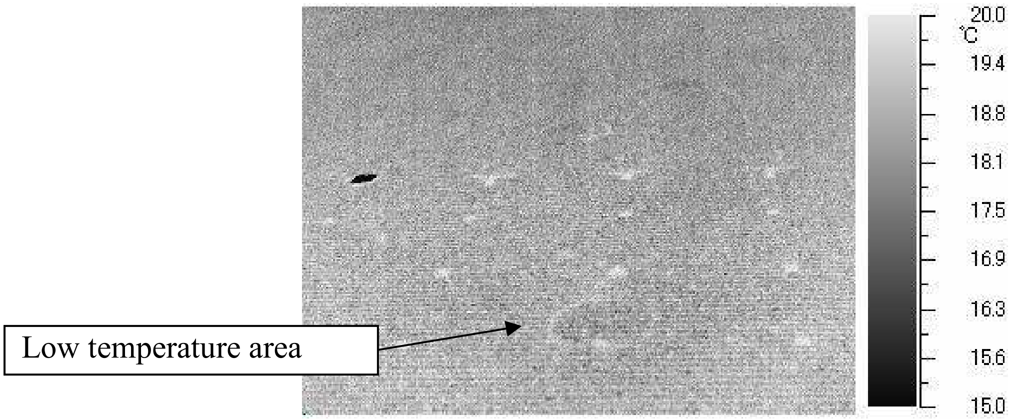
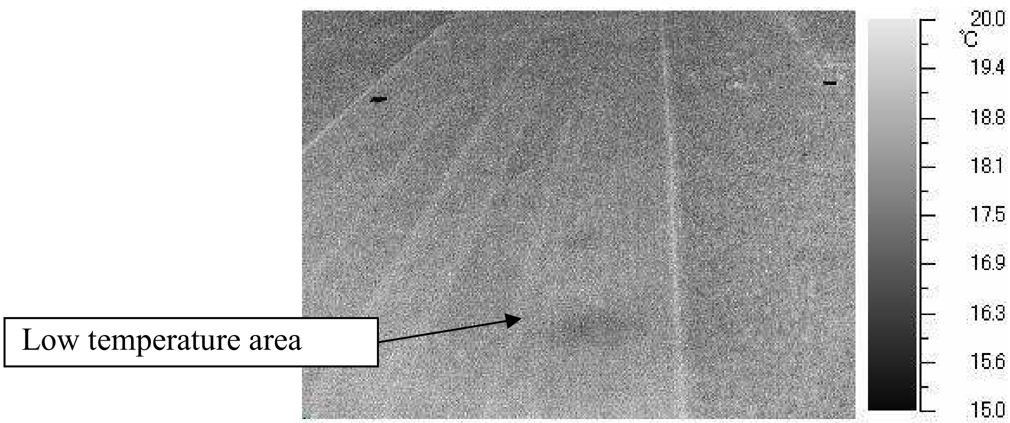


Figure 9. Dimension of Grooves.

Figure 10 shows infrared images taken from the same height (about 3 m) and same range of temperature (15 - 20°C) but at different depression angle. It was easy to see the black (low-temperature) areas in infrared images at the depression angle of 10°, whereas the striped pattern due to grooves could be seen clearly and the black (low-temperature) areas could not be easily seen in infrared images at the depression angle of 20°. Thus, infrared images should be taken at a low depression angle to enable the inspector to identify the de-bonded areas in grooved runways and taxiways.



(a) Depression Angle of 20°.



(b) Depression Angle of 10°.

Figure 10. Infrared Iimages at Different Depression Angles.